

**In the Specification:**

Please replace the paragraphs [0037], [0038], [0041], [0044], [0045], [0047], [0050], [0051], [0052], [0053], [0055], [0056], [0067], [0068], [0070], and [0071] as follows:

[0037] A temperature controlled substrate support assembly 238 is centrally disposed within the processing chamber 202. The support assembly 238 supports a glass substrate 240 during processing. In one embodiment, the substrate support assembly 238 comprises an aluminum body 224 that encapsulates at least one embedded heater 232. The heater 232, such as a resistive element, disposed in the support assembly 238, is coupled to an optional power source 274 and controllably heats the support assembly 238 and the glass substrate 240 positioned thereon to a predetermined temperature. Typically, in a CVD process, the heater 232 maintains the glass substrate 240 at a uniform temperature between about 150 to at least about 460 degrees Celsius, depending on the deposition processing parameters for the material being deposited.

[0038] Generally, the support assembly 238 has a lower side 226 and an upper side 234. The upper side 234 supports the glass substrate 240. The lower side 226 has a stem 242 coupled thereto. The stem 242 couples the support assembly 238 to a lift system (not shown) that moves the support assembly 238 between an elevated processing position (as shown) and a lowered position that facilitates substrate transfer to and from the processing chamber 202. The stem 242 additionally provides a conduit for electrical and thermocouple leads between the support assembly 238 and other components of the system 200.

[0041] The support assembly 238 additionally supports a circumscribing shadow frame 248. Generally, the shadow frame 248 prevents deposition at the edge of the glass substrate 240 and support assembly 238 so that the substrate does not stick to the support assembly 238. The support assembly 238 has a plurality of holes 228 disposed therethrough that accept a plurality of lift pins 250. The lift pins 250 are

typically comprised of ceramic or anodized aluminum. The lift pins 250 may be actuated relative to the support assembly 238 by an optional lift plate 254 to project from the support surface 230, thereby placing the substrate in a spaced-apart relation to the support assembly 238.

[0044] The gas distribution plate assembly 218 is coupled to an interior side 220 of the lid assembly 210. The gas distribution plate assembly 218 is typically configured to substantially follow the profile of the glass substrate 240, for example, polygonal for large area flat panel substrates and circular for wafers. The gas distribution plate assembly 218 includes a perforated area 216 through which process and other gases supplied from the gas source 204 are delivered to the process volume 212. The perforated area 216 of the gas distribution plate assembly 218 is configured to provide uniform distribution of gases passing through the gas distribution plate assembly 218 into the processing chamber 202. Gas distribution plates that may be adapted to benefit from the invention are described in commonly assigned United States Patent Application Serial Nos. 09/922,219, filed August 8, 2001, issued as United States Patent No. 6,772,827, by Keller et al.; 10/140,324, filed May 6, 2002; and 10/337,483, filed January 7, 2003 by Blonigan et al.; United States Patent No. 6,477,980, issued November 12, 2002 to White et al.; and United States Patent Application Serial Nos. 10/417,592, filed April 16, 2003 by Choi et al., which are hereby incorporated by reference in their entireties.

[0045] The gas distribution plate assembly 218 typically includes a diffuser plate 258 suspended from a hanger plate 260. The diffuser plate 258 and hanger plate 260 may alternatively comprise a single unitary member. A plurality of gas passages 262 are formed through the diffuser plate 258 to allow a predetermined distribution of gas passing through the gas distribution plate assembly 218 and into the process volume 212. The hanger plate 260 maintains the diffuser plate 258 and the interior surface 220 of the lid assembly 210 in a spaced-apart relation, thus defining a plenum 264 therebetween. The plenum 264 allows gases flowing through the lid assembly 210 to uniformly distribute across the width of the diffuser plate 258 so that gas is provided

uniformly above the center of perforated area 216 and flows with a uniform distribution through the gas passages 262.

[0047] Figure 3 is a partial sectional view of the diffuser plate 258 that is described in commonly assigned United States Patent Application Serial No. 10/227,483, titled "Tunable Gas Distribution Plate Assembly", filed on January 7, 2003. For example, for a 1080 in<sup>2</sup> (e.g. 30 inches X 36 inches) diffuser plate, the diffuser plate 258 includes about 16,000 gas passages 262. For larger diffuser plates used to process larger flat panels, the number of gas passages 262 could be as high as 100,000. The gas passages 262 are generally patterned to promote uniform deposition of material on the substrate 240 positioned below the diffuser plate 258. Referring to Figure 3, in one embodiment, the gas passage 262 is comprised of a restrictive section 302, a flared connector 303, a center passage 304 and a flared opening 306. The restrictive section 302 passes from the first side 318 of the diffuser plate 258 and is coupled to the center passage 304. The center passage 304 has a larger diameter than the restrictive section 302. The restrictive section 302 has a diameter selected to allow adequate gas flow through the diffusion plate 258 while providing enough flow resistance to ensure uniform gas distribution radially across the perforated center portion 310. For example, the diameter of the restrictive section 302 could be about 0.016 inch. The flared connector 303 connects the restrictive section 302 to the center passage 304. The flared opening 306 is coupled to the center passage 304 and has a diameter that tapers radially outwards from the center passage 304 to the second side 320 of the diffuser plate 258. The flared openings 306 promote plasma ionization of process gases flowing into the processing regions 212 ~~and 214~~. Moreover, the flared openings 306 provide larger surface area for hollow cathode effect to enhance plasma discharge.

[0050] The spacing between flared edges of adjacent gas passages 262 should be kept as small as possible. The flared edges could be rounded. An example of the spacing is 0.05 inch. The maximum spacing between flared edges of adjacent gas passages 262 is about 0.5 inch. The total restriction provided by the restrictive section 402 directly affects the back pressure upstream of the diffuser plate 258, and

accordingly should be configured to prevent re-combination of disassociated fluorine utilized during cleaning. The ratio of the length (411) of the restrictive section 402 to the length (412) of the conical opening 406 is between about 0.8 to about 2.0. The total thickness of diffuser plate, which equals the summation of length 411 and length 412, is between about 0.8 inch to about 1.6 inch. The conical openings 406 promote plasma ionization of process gases flowing into the processing regions 212 and 244. An example of the quad-aperture gas passage design has the restrictive section 402 diameter at 0.042 inch, the length of the restrictive section 402 at 0.0565 inch, the conical opening 406 diameter on the second side 420 of the diffuser plate 258 at 0.302 inch, the length of the conical opening section at 0.0635 inch, and the flaring angle 416 at 22°. The total thickness of the exemplary diffuser plate is 1.2 inches.

[0051] Figure 4B shows a section of an exemplary embodiment of a hexagonal close pack gas diffuser plate 258. The holes 450 (or gas passages 262 described earlier) are arranged in a pattern of face centered hexagons 460. The ~~sized~~ size of diffuser holes, and the spacing of diffuser holes are not drawn to scale in Figure 4B. However, other patterns of gas passages 262 arrangement (or holes 450), such as concentric circles, can also be used.

[0052] Figure 4C shows an alternative design to the design shown in Figure 4A. During the manufacturing process of machining the restrictive section 402 and the ~~flared section~~ conical opening 406, a flared connecting section 405 could be created by using a different drill to round up (or remove) the burrs left during drilling sections 402 and conical opening 406. Aside from the addition of this connecting section 405, the rest of design attributes of Figure 4C are the same as the design attributes of Figure 4A.

[0053] Comparing the quad-aperture design in Figure 3 and the funnel design in Figure 4A, ~~one can see that~~ the funnel design diffuser plate is easier to manufacture than the quad-aperture design diffuser plate. Funnel design in Figure 4A requires drilling of 2 sections which include the restrictive section 402 and the conical section

406; while the quad-aperture design in Figure 3 requires drilling of 4 sections: the restrictive section 302, flared connector 303, center passage 304 and flared opening 306. Drilling of 2 sections to meet the manufacturing specification is much easier than drilling of 4 sections to meet the manufacturing specification. The funnel design in Figure 4A also ~~would have~~ has higher manufacturing yield than the quad-aperture design in Figure 3 due to lower total number of holes. For example, for a 1080 in<sup>2</sup> (e.g. 30 inches X 36 inches) diffuser plate, the funnel design has about 12,000 holes, while the quad-aperture design has about 16,000 holes. The funnel design diffuser plate has about 30% percent less holes than the quad-aperture design diffuser plate. In addition, the funnel design in Figure 4A has fewer particle problems than the quad-aperture design in Figure 3 due to its relative simplicity in removing broken drill bits from the larger restrictive section 402 (e.g. 0.040 inch and 0.055 inch), compared to the smaller restrictive section 302 (e.g. 0.016 inch).

[0055] A film deposition chamber requires periodic cleaning to reduce the film ~~build up~~, build-up along chamber surfaces which might flake off to create particle problems[[,]] in the process chamber. An example of the cleaning process is the remote plasma source (RPS) clean, which utilizes fluorine containing plasma, generated from fluorine containing gases, such as NF<sub>3</sub>, SF<sub>6</sub>, F<sub>2</sub>, C<sub>2</sub>F<sub>6</sub>, C<sub>3</sub>F<sub>6</sub> or C<sub>4</sub>F<sub>8</sub>O etc., to clean. After the cleaning step, a purge gas is used to purge out residual fluorine; however, some residual fluorine species might remain on the chamber and diffuser plate surface areas. The darkened lines (501) in Figure 5 show the funnel design diffuser surface exposed to the process volume 212. Table 1 compares the total exposed surface areas of two funnel designs (0.040 inch and 0.055 inch restrictive section diameters) and a quad-aperture design. The diameter of the flared end of both funnel designs is 0.302 inch and the flaring angle is 22°. The restrictive section 402 length for both funnel designs is 0.565 inch, while the length of the flared opening 406 for both designs is 0.635 inch. As for the quad-aperture design, the diameter of the restrictive section 302 is 0.016 inch, the diameter of the center passage 304 is 0.156 inch, the large diameter of the flared opening 306 is 0.25 inch and the flaring angle is 22°, the length of restrictive section is 0.046 inch, the length of the flared connector 303

is 0.032 inch, the length of the center passage 304 is 0.88 inch and the length of the flared opening 306 is 0.242 inch. The quad-aperture design has highest number of diffuser holes and highest total diffuser surface area. Both 0.040 inch and 0.055 inch funnel designs have relatively close total exposed diffuser surface areas, which are about half the total exposed diffuser surface area of the quad-aperture design.

[0056] Figure 6 shows an example of a process flow 600 of depositing a thin film on a substrate in a process chamber with a gas diffuser plate and cleaning the process chamber when cleaning is required. The process starts at step 601, followed by step 602 of placing a substrate in a process chamber with a diffuser plate. Step 603 describes depositing a thin film on the substrate in the process chamber. After step 603, the system decides whether the number of processed substrates has reached a pre-determined cleaning limit at step 604. The pre-determined cleaning limit could be 1 substrate or more than 1 substrate at step 606. If the cleaning limit has not been reached, the process sequence goes back to step 602 of placing another substrate in the process chamber. If the cleaning limit has reached the pre-determined cleaning limit, the process sequence goes to step 605 of cleaning the process chamber. After chamber cleaning at step 605, the system decides whether the number of total processed substrates has reached a pre-determined limit. If the cleaning limit has not been reached, the process sequence goes back to step 601 of starting the deposition process. If the cleaning limit has been reached the pre-determined limit, the deposition process stops at step 607. Process flow 600 is only used as an example to demonstrate the concept. The invention can also apply to process flows that involves other process steps or sequences, but fit into the general concept of deposition and cleaning.

[0067] In addition to cleaning efficiency, the impact of the diffuser design on the deposition performance should also be examined to ensure deposition performance ~~meet~~ meets the requirements. Table 7 compares the SiN and  $\alpha$ -Si deposition uniformities and rates using the different diffuser designs under the same process conditions for the 3 diffuser designs. The SiN film is deposited using 600 sccm SiH<sub>4</sub>,

2660 sccm NH<sub>3</sub> and 6660 sccm N<sub>2</sub>, under 1.5 Torr and 3050 watts source power. The spacing between the diffuser plate and the support assembly is 1.09 inch. The process temperature is maintained at about 355 °C. The  $\alpha$ -Si film is deposited using 1170 sccm SiH<sub>4</sub> and 4080 sccm H<sub>2</sub>, under 3.0 Torr and 950 watts source power. The spacing between the diffuser plate and the support assembly is 1.09 inch. The process temperature is maintained at 355 °C.

[0068] The results show that the deposition rates and uniformities of the three designs are relatively comparable. The deposition rates are about the same for the three designs. The uniformity of 0.055 inch funnel design is worse than the quad-aperture design. However, the uniformity can be improved by narrowing the diameter of the restrictive section 402 (0.040 inch vs. 0.055 inch). The uniformity of 0.040 inch funnel design (3.2% and 4.4%) is better than 0.055 inch funnel design (4.3% and 4.5%). For SiN film, the 0.040 inch funnel design (3.2%) is even better than the quad-aperture design (3.8%). Other film properties, such as film stress, reflective index, and wet etch rate, are equivalent for the three designs. The results show that the film uniformity is affected by the diffuser design and can be tuned by adjusting the diameter of the restrictive section. The results also show that the funnel design can achieve the same deposition properties, such as uniformity, deposition rate, film stress, reflective index and wet etch rate, as the quad-aperture design.

[0070] The funnel design diffuser plate is easier to manufacture compared to the quad-aperture design diffuser plate. Therefore, the yield and cost of manufacturing the funnel design diffuser plate ~~would be~~ is improved. In addition to ease of manufacturing, the funnel design diffuser plate also has the benefit of less residual fluorine on the diffuser plate after RPS clean. This results in less fluorine incorporation in the gate dielectric films and improved device performance. The funnel design could have better or equivalent clean rate and efficiency compared to the quad-aperture design, depending on the diameter of the restrictive section 402 selected. The funnel design also could have deposition rate and uniformity performance equivalent to the quad-aperture design.

[0071] For a flat panel display with larger surface area, diffuser plate 258 with larger top surface area 420 would be required. With the increase of top surface area 420, the thickness of the diffuser plate 258 could increase to maintain the strength in supporting the diffuser plate. Figure 8A shows a variation of the funnel design in Figure 4A for a thicker diffuser plate. All the corresponding design attributes of Figure 8A are same as Figure 4A. The guidelines used to design the restrictive section 802, the flared section 806, and flaring angle 816 are similar to the guideline used to design the restrictive section 402, the conical section opening 406, and flaring angle ~~816~~ 416 of Figure 4A respectively. The presently preferred configuration of the flared section 806 is the conical cross-section shown in Figure 8A. However, other configurations including concave cross-sections, such as parabolic, and convex cross-sections, can be used as well. The difference between Figure 8A and Figure 4A is that Figure 8A is thicker by the length 801 ~~layer~~. A larger diameter section 804 can be created between the first side 818 of the diffuser plate 258 and the restrictive section 802. The large diameter section 804 is connected to the restrictive section 802 by a flared connector 803. During the manufacturing process of machining the restrictive section 802 and the larger diameter section 804, the flared connecting section 803 is created by using a different drill to round up (or remove) the burrs left during drilling sections 802 and 804. Since the large diameter section 804 has larger diameter than restrictive section ~~804~~ 802, it only slightly ~~increase~~ increases the manufacturing time and does not affect manufacturing yield. The diameter of the larger diameter section 804 should be at least 2 times the diameter of the restrictive section 802 to ensure that the addition of the larger diameter section also does not change the backpressure and chamber pressure during processing as compared to the funnel design in Figure 4A. Due to this, the deposition process and the qualities of the film deposited using the design in Figure 8A are similar to the deposition process and the qualities of the film deposited by the funnel design of Figure 4A. The larger diameter section 804 has a diameter between about 0.06 inch to about 0.3 inch. The edges of the larger diameter section 804 of the diffuser holes on the first side 818 of the diffuser plate 258 could be rounded. The ratio of the length 801 of the larger diameter section to the length 811 of the restrictive



section 802 should be between about 0.3 to about 1.5. The total thickness of the diffuser plate, which equals the summation of length 801, length 811 and length 812, is between about 1.0 inch to about 2.2 inch.